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Original Research

Effectiveness of contact tracing and quarantine on reducing COVID-19 transmission: a retrospective cohort study

R. Malheiro*, A.L. Figueiredo, J.P. Magalhães, P. Teixeira, I. Moita, M.C. Moutinho, R.B. Mansilha, L.M. Gonçalves, E. Ferreira

Administração Regional de Saúde do Norte, Unidade de Saúde Pública do ACES Grande Porto VI – Porto Oriental, Rua de Vale Formoso, 466, 4200-510, Porto, Portugal

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A B S T R A C T

Objectives: Contact tracing and quarantine are common measures used in the management of infectious disease outbreaks. However, few studies have measured their impact on the control of the COVID-19 pandemic. This study aimed to assess the effectiveness of those measures on reducing transmission of severe acute respiratory syndrome coronavirus 2 in a community setting.
Study design: The study design is a retrospective cohort study.
Methods: A retrospective cohort study of COVID-19 cases notified in Eastern Porto from March 1st to April 30th, 2020 was performed. Intervention and control cohorts were defined based on whether cases were subjected to contact tracing and quarantine measures before the laboratory confirmation of disease. The number of secondary cases per index case and the proportion of cases with subsequent secondary cases were the primary outcomes. Secondary outcomes included the time from symptom onset to specimen collection and the number of close contacts. The analysis was stratified according to whether national lockdown measures had already been implemented.
Results: The intervention and control cohorts comprised 98 and 453 cases, respectively. No differences were observed concerning primary outcomes. The intervention group had a shorter time between symptom onset and specimen collection (median: 3 days, interquartile range [IQR]: 1–6, vs. median: 5 days, IQR: 2–7, *P*-value = 0.004) and fewer close contacts (median: 0, IQR: 0–2, vs. median: 2, IQR: 1–4, *P*-value<0.001). The stratified analysis returned similar results.
Conclusion: Local public health measures were effective in reducing the time between symptom onset and laboratory diagnosis and the number of close contacts per case. No effect was apparent on secondary case figures, suggesting that further measures may be required.
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Introduction

Ever since it was reported in Hubei, China,[1] the disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), known as COVID-19, has spread globally. As of August 10th, 2020, there had been 19,718,030 confirmed cases of COVID-19 worldwide, with 728,013 reported deaths.[2] COVID-19 is primarily transmitted between people through respiratory droplets and contact routes,[3–5] and the most common symptoms are fever, cough, fatigue, headache, and, in severe cases, dyspnea and severe acute respiratory syndrome.[3,4,6–8]

Understanding the route of transmission is essential to implement adequate measures to respond to the outbreak. As individuals who were in close contact with a confirmed case are at increased risk of being infected,[4,9,10] contact tracing and quarantine are primary actions at reducing the number of secondary cases and controlling the outbreak.[11,12] The rationale is straightforward. Close contacts may become symptomatic up to 14 days after their last contact with a confirmed case.[5,13] If they do so while quarantined, the transmission chain is broken. Furthermore, as the transmission risk is higher around the time of symptom onset of the index case and may even occur up to 48 h before symptom onset, contact tracing may only be effective if performed at an early stage of the disease.[5,11,12,14,15]

* Corresponding author. Administração Regional de Saúde do Norte, ACE Grande Porto VI – Unidade de Saúde Pública Porto Oriental, Rua de Vale Formoso, 466, 4200-510, Porto, Portugal. Tel.: +351 914 311 311; fax: +220 419 965.
E-mail address: rui.coelho@arsnorte.min-saude.pt (R. Malheiro).

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In Portugal, three key factors played a significant role in allowing nationwide contact tracing. First, considerable resources were committed by political and health sectors to allow testing of every suspect case, both at hospital and community settings. Second, there is a national epidemiological surveillance system[16] that allows physicians to opportunely report every case to public health authorities. Third, there is an experienced public health workforce in outbreak management across the country.

On March 18th, Portugal declared the state of emergency, which came into force 4 days later, and was extended until May 2nd. Similarly to other European countries, it consisted of lockdown measures,[17] including constraints in public circulation, closure of commercial activities, and resort to homeworking. On March 26th, the mitigation phase was declared nationwide. Consequently, all patients with new-onset respiratory infection symptoms met the laboratory testing criteria, regardless of whether they had been in close contact with a confirmed COVID-19 case – prior to this day, only symptomatic close contacts of a confirmed case were tested.

So far, few studies have addressed the effectiveness of contact tracing and quarantine to control this new pandemic.[10–12,18,19] Most studies have been carried out in countries with markedly different health systems, resources, and political organizations.

This study aimed to assess the effectiveness of contact tracing and quarantine measures (in combination with case isolation) on reducing transmission of SARS-CoV-2 in Eastern Porto, Portugal, from March 1st, 2020 to May 15th, 2020.

Methods

Setting

In Portugal, since January 25th, 2020, physicians are mandated to report all suspected and confirmed COVID-19 cases through a centralized disease notification system called the National Epidemiological Surveillance System (SINAVE). Case investigation is immediately conducted by local public health authorities, with the implementation of the following measures for a confirmed case: isolation, contact tracing, and mandatory quarantine of close contacts. The Public Health Authority of Eastern Porto operates at the community level in the three easternmost parishes of Porto city, which comprise an urban area with more than 100,000 people, and coordinates the public health investigation and response to COVID-19 regarding all individuals currently living in that area.

Study design and participants

We conducted a retrospective cohort study of all COVID-19–confirmed cases notified to the public health authority between March 1st, 2020, and April 30th, 2020. Cases arising in nursing homes' residents and patients admitted to the hospital before 2 days before symptom onset or a positive test result for SARS-CoV-2 (if asymptomatic) were excluded. Cases we were unable to contact within 14 days after their diagnosis and cases in which it was unclear whether they were a contact of a known case were also excluded.

Definitions

A COVID-19–confirmed case was defined as an individual with a positive test for SARS-CoV-2 on an upper respiratory tract sample by reverse transcription polymerase chain reaction, regardless of their symptomatic status.

Contact tracing was defined as the systematic identification, through a detailed interview with the patient with COVID-19 or their caregiver, of all household, family, work/school, and social contacts who have had contact with a confirmed case, from 2 days before symptom onset of the case and up to 14 days afterward. Identified contacts were then classified into close and casual contacts and informed of their exposure. Close contacts (high risk) were defined as individuals who have spent 15 min or more in close proximity (2 m or less) to, or in a closed space with, a case.

All close contacts were placed under mandatory quarantine and assessed once daily, by telephone, for potential symptoms of COVID-19. Follow-ups of close contacts ended 14 days after the last exposure or if the contact was, in the meantime, diagnosed with COVID-19. Work-related contacts of healthcare and nursing home staff were excluded, as they were identified and managed following different guidelines. Close contacts with fever (temperature $\geq$38°C), cough, dyspnea, and/or other mild symptoms were transferred directly to a healthcare facility for further evaluation and testing.

The intervention group comprised all COVID-19–confirmed cases that were either identified as close contacts of an index case or returned from affected areas and placed under mandatory quarantine, with daily follow-up until laboratory confirmation of SARS-CoV-2 infection. The control group included all COVID-19–confirmed cases that were not subject to contact tracing nor to quarantine measures preceding the diagnosis.

Data collection and sources

Data on demographic characteristics, including sex, age at notification, and type of dwelling (social or not), were collected. Epidemiological parameters, namely notification date, symptomatic status, symptom onset date, specimen collection date, the number and type of close contacts, the number of total household members, and the number of household members without a positive test result for SARS-CoV-2 at the time contact tracing began, were also collected. Data source was the notification database of the SINAVE and protected databases used for the daily monitoring and registration of close contacts for follow-up.

Outcome measures

The median number of secondary cases by index case and the proportion of cases with secondary cases were the primary outcome measures of the study. Secondary outcomes include median time from symptom onset to specimen collection and median number of close contacts. The rationale for the secondary outcomes is that, by identifying cases as soon as possible, secondary cases may be further reduced.

Statistical analysis

Categorical variables are presented as frequencies and percentages and continuous variables as medians and interquartile ranges (IQRs). The Shapiro-Wilk test was used to assess normality.

Attack rates were calculated by dividing the number of secondary cases by the number of close contacts.

Chi-squared and Mann-Whitney U tests were used to evaluate the distributions of categorical and continuous variables, respectively, between the intervention and control groups.

Considering the potential confounding introduced by national lockdown measures, we repeated the analysis resorting to stratification. Because the incubation period for COVID-19 is, on average, 5–6 days,[3,12,13,15] we decided to set a lag of 7 days from the Decree's execution date, by selecting March 29th as the cutoff point after which the effects of lockdown measures may have become apparent.

Analyses were performed using Microsoft Excel 2016 and R, version 4.0.0.

Table 1
Demographic and epidemiological parameters among intervention (cases under quarantine and daily follow-up at the time of diagnosis) and control cohorts.

Parameters	Intervention N = 98	Control N = 453	*P*-value
Age in years [median (IQR)]	50.5 (34.2–66)	53 (36–67)	0.233
Female sex [n (%)]	51 (52.0)	273 (60.2)	0.166
Social neighborhood dwellers [n (%)]	29 (29.6)	69 (15.2)	0.198
Asymptomatic [n (%)]	12 (12.2)	26 (5.7)	0.037*
Total number of close contacts	132	1495	–
Total number of secondary cases	16	138	–
Attack rate [% (95%CI)]	12.1 (7.1–18.9)	9.2 (7.8–10.8)	0.125
Attack rate by case [median (IQR)]	0 (0–0)	0 (0–0)	0.755
Household members [median (IQR)]	2 (1–3)	2 (1–2.5)	0.006*
Non-infected household members [median (IQR)]	1 (0–2)	1 (0–2)	0.306
Time between symptom onset and notification date in days [median (IQR)]	3 (1–6)	5 (2–7)	0.006*
Time between specimen collection date and notification date in days [median (IQR)]	1 (0–3)	1 (0–3)	0.936
Secondary cases detected by index case [median (IQR)]	0 (0–0)	0 (0–0)	0.245
Cases with secondary cases [n (%)]	13 (13.3)	78 (17.2)	0.406
Time between symptom onset and specimen collection date in days [median (IQR)]	3 (1–6)	5 (2–7)	0.004*
Number of close contacts [median (IQR)]	0 (0–2)	2 (1–4)	<0.001*

CI = confidence interval, IQR = interquartile range, **P* < 0.005.

Results

Of 630 COVID-19 cases reported to the public health authority during the study period, 551 (87.5%) were considered for the analysis. The intervention and control cohorts comprised 98 (17.8%) and 453 (82.2%) cases, respectively. Most excluded cases were nursing homes' residents (45), followed by uncontacted (17) and hospitalized patients (11).

Overall sociodemographic characteristics of both cohorts are presented in Table 1. Among the intervention cohort, 16 of 132 close contacts tested positive during the follow-up period (attack rate: 12.1%, 95% confidence interval [CI]: 7.1–18.9). In the control cohort, 138 of 1495 participants tested positive (attack rate: 9.2%, 95% CI: 7.8–10.8). The median number of household members was higher in the intervention group, with a median of 2 (IQR: 1–3) vs. a median of 2 (IQR: 1–2.5) in the control cohort (*P*-value = 0.006), although no difference was found when accounting solely for household members without a positive test result for SARS-CoV-2 at the time contact tracing began.

No differences were observed between groups when comparing the median number of secondary cases by index case and the proportion of cases with secondary cases.

Time between symptom onset and specimen collection was significantly shorter for the intervention group, with a median of 3 days (95% CI: 2–4 days), compared with a median of 5 days (95% CI: 4–5 days) in the control group.

Cases under mandatory quarantine and daily follow-up at the time of diagnosis showed a significantly lower median number of close contacts (median: 2, IQR: 1–4) when compared with the control group (median: 0, IQR: 0–2, *P*-value<0.001).

As observed in Table 2, for both groups, household contacts were the most frequent type of close contact identified: 95 (72.0%) and 685 (45.8%) for intervention and control groups, respectively. Similarly, for both groups, the majority of secondary cases developed in household members: 11 (68.8%) vs. 72 (52.1%), respectively. The distribution of close contacts and secondary cases by type of close contact categorization was significantly different across cohorts (*P*-value<0.001 and *P*-value = 0.036, respectively).

No difference was observed on the number of asymptomatic cases between cohorts, either in the period before or after the state of emergency at a 7-day lag (Table 3). The overall proportion of asymptomatic cases after lockdown measures (35 cases, 10.7%) was higher than before they were implemented (3 cases, 1.4%, *P*-value<0.001).

Before the state of emergency at a 7-day lag, the intervention group had a median of 3 household members (IQR: 1–3) and the control group had a median of 2 (IQR 1–3), a difference that was found to be significant (*P*-value = 0.026). Such difference was not observed afterward. There were no differences in the median number of household members between the cases reported during both time periods.

The median number of secondary cases by index case was lower for the cases reported under the state of emergency at a 7-day lag (median: 0, IQR: 0-0, in both periods, *P*-value = 0.039), with no difference between cohorts.

Table 2
Distribution of close contacts and secondary cases between intervention (cases under quarantine and daily follow-up at the time of diagnosis) and control cohorts, by type of close contact.

Type of close contact	Intervention		Control		*P*-value (for contact distribution)	*P*-value (for case distribution)
	Close contacts (n, % of total)	Secondary cases (n, % of total)	Close contacts (n, % of total)	Secondary cases (n, % of total)		
Total (n)	132 (100)	16 (100)	1495 (100)	138 (100)	<0.001*	0.036*
Household	95 (72.0)	11 (68.8)	685 (45.8)	72 (52.1)		
Family	6 (4.6)	0 (00.0)	205 (13.7)	20 (14.5)		
Work/school	24 (18.2)	5 (31.3)	378 (25.3)	20 (14.5)		
Social	7 (05.3)	0 (00.0)	225 (15.1)	26 (18.8)		
Missing	0 (00.0)	0 (00.0)	2 (13.4)	0 (0.0)		

**P* < 0.005.

Table 3
Demographic and epidemiological parameters among intervention (cases under quarantine and daily follow-up at the time of diagnosis) and control cohorts, before and after the state of emergency decree, with a 7-day lag.

Parameters	Before state of emergency, with 7-day lag				After state of emergency, with 7-day lag				*P*-value (for the periods)
	Total	Intervention	Control	*P*-value	Total	Intervention	Control	*P*-value	
	N = 222	N = 27	N = 195		N = 329	N = 71	N = 258		
Age in years [median (IQR)]	52 (34–64)	44 (21.5–56.5)	53 (35–64)	0.055	52 (36–68)	52 (36.5–68)	53 (36–68.8)	0.758	0.495
Female sex [n (%)]	123 (55.4)	15 (55.6)	108 (55.4)	1	201 (61.1)	36 (50.7)	165 (64.0)	0.059	0.214
Social neighborhood dwellers [n (%)]	44 (19.8)	6 (22.2)	38 (19.5)	0.949	88 (26.8)	23 (32.4)	65 (25.2)	0.296	0.077
Asymptomatic [n (%)]	3 (1.4)	1 (3.7)	2 (1.0)	0.810	35 (10.7)	11 (15.5)	24 (9.3)	0.200	<0.001*
Total number of close contacts	957	46	911	–	670	86	584	–	–
Total number of secondary cases	88	3	85	–	66	13	53	–	–
Attack rate [% (95% CI)]	9.2 (7.4–11.2)	6.5 (1.4–17.9)	9.3 (7.5–11.4)	0.703	9.9 (7.7–12.4)	15.1 (8.3–24.5)	9.1 (6.9–11.7)	0.118	0.720
Attack rate by case [median (IQR)]	0 (0–0.8)	0 (0–0)	0 (0–5.7)	0.306	0 (0–0)	0 (0–12.5)	0 (0–0)	0.217	0.318
Household members [median (IQR)]	2 (1–3)	3 (1–3)	2 (1–3)	0.026*	2 (1–3)	2 (1–3)	2 (1–2)	0.0703	0.913
Non-infected household members [median (IQR)]	1 (0–2)	1 (0–2)	1 (0–2)	0.619	1 (0–2)	1 (0–2)	1 (0–2)	0.337	0.752
Time between symptom onset and notification date in days [median (IQR)]	6 (4–9.5)	5 (3–10.5)	7 (4–9)	0.122	6 (3–11)	5.5 (3–9.25)	7 (3–11)	0.141	0.746
Time between specimen collection date and notification date in days[median (IQR)]	1 (1–3)	1 (1–4)	1 (1–3)	0.451	1 (0–3)	1 (0–3)	1 (0–3)	0.878	0.162
Secondary cases detected by index case [median (IQR)]	0 (0–0)	0 (0–0)	0 (0–0)	0.807	0 (0–0)	0 (0–0)	0 (0–0)	0.912	0.039*
Cases with secondary cases [n (%)]	45 (20.3)	3 (11.1)	42 (21.5)	0.314	46 (14.0)	10 (14.1)	36 (14.0)	1	0.067
Time between symptom onset and specimen collection date in days [median (IQR)]	5 (2–7)	3.5 (2–5.8)	5 (3–7)	0.113	4 (2–7)	3 (1–6)	5 (2–8)	0.025*	0.417
Number of close contacts [median (IQR)]	2 (1–5)	1 (0–2.5)	2 (1–5)	0.002*	2 (0–3)	0 (0–2)	2 (1–3)	<0.001*	<0.001*

CI = confidence interval, IQR = interquartile range, *$P < 0.005$.

Time between symptom onset and specimen collection was significantly shorter for the intervention group during the state of emergency (median of 3 days, IQR: 1–6, vs. median of 5 days, IQR: 2–8, *P*-value = 0.025) but not before it (median of 3.5 days, IQR: 2–5.8, vs. median of 5 days, IQR: 3–7, *P*-value = 0.113). The intervention group had a significantly lower median number of close contacts in the period before the cutoff point (median of 1, IQR: 0–2.5, vs. median of 2, IQR: 1–5, *P*-value = 0.002) and in the period after (median of 0, IQR: 0–2, vs. median of 2, IQR: 1–3, *P*-value<0.001). The median number of close contacts was also lower for the cases reported under the state of emergency at a 7-day lag (median of 2, IQR: 0–3, vs. median of 2, IQR: 1–5, *P*-value<0.001).

The proportion of household members among total contacts increased significantly from 35.9% (*N* = 343) to 65.2% (*N* = 437, *P*-value<0.001), after the state of emergency (Table 4).

Discussion

In the present study, contact tracing and quarantine of close contacts appear to have no role in reducing the number of secondary cases of COVID-19. This finding has been suggested by previous studies. Ngonghala et al.[18] predicted that contact tracing would be, at best, marginally effective in minimizing the burden of the disease and would not even be necessary if case isolation was effectively implemented. Similarly, a review of public health measures concluded that, while quarantine alone is an important outbreak control measure *per se*, it seems to be insufficient to contain COVID-19, reporting that presymptomatic infectiousness and a basic reproduction number of, or greater than, 2.5 negatively influence its effectiveness.[20] It is relevant to consider that because COVID-19 attack rate is relatively low,[12] there is a small number of secondary cases at baseline. Thus, the small gap for a further significant decrease may justify the apparent ineffectiveness of local measures. Moreover, the distribution of close contacts by type in intervention and control groups was markedly different and changed considerably after the execution of the state of emergency, with a greater proportion of household members as high-risk contacts. This has a direct impact on the effectiveness assessment. In many situations, housing conditions were unable to guarantee true isolation of the patient with COVID-19, meaning that cohabitants remained at risk of being infected.[21] Thus, the transmission chain was not broken immediately after the identification and isolation of the index case but only after all household members became infected. In the future, it may be interesting to assess the effectiveness of local measures using the household as the unit of measurement rather than individuals. Despite the small numbers, the state of emergency, considering the 7-day lag, does seem to have had an impact on the number of secondary cases per index case.

Considering our secondary outcomes, we found that suspected cases were diagnosed more rapidly if they were previously traced as close contacts of a case and daily monitored during the incubation period of COVID-19. As soon as the physician detected a symptom compatible with COVID-19 throughout the follow-up period, contacts were immediately tested. The diagnosis was thus enhanced, often when contacts were still in a paucisymptomatic stage of the disease. Time saved by daily monitoring of close contacts meant that fewer people were exposed to the new case and those who happened to be exposed were so for a shorter period of time. The mitigation phase was expected to primarily affect the control cohort, as previously reported,[15] and therefore, one might have anticipated that the effect of contact tracing and quarantine measures on the time between symptom onset and specimen collection would only be detectable in the containment phase. Unexpectedly, the opposite was found, as the effect of those

Table 4
Distribution of close contacts between intervention (cases under quarantine and daily follow-up at the time of diagnosis) and control cohorts, by type of close contact and before and after the state of emergency decree, with a 7-day lag.

Type of close contact	Before state of emergency, with 7-day lag				After state of emergency, with 7-day lag				*P*-value
	Total	Intervention	Control	*P*-value	Total	Intervention	Control	*P*-value	
	N = 955	N = 46	N = 909		N = 670	N = 86	N = 584		
Household members [n (%)]	343 (35.9)	31 (67.4)	312 (34.3)	<0.001*	437 (65.2)	64 (74.4)	373 (63.9)	0.072	<0.001*
Other [n (%)]	612 (64.1)	15 (32.6)	597 (65.7)		233 (34.8)	22 (25.6)	211 (36.1)		

*$P < 0.005$.

measures was only evident after the national declaration of the state of emergency (at a 7-day lag), that is, during the mitigation phase. Before the state of emergency decree, there were only 27 cases in the intervention cohort, meaning that the absence of differences between groups in the containment phase may actually be due to a lack of statistical power.

As expected, cases in the intervention cohort had fewer close contacts than their counterparts, thereby supporting the notion that most people complied with public health authorities' recommendations and orientations. The decrease in the median number of close contacts seemed to have been due to a synergistic effect of both local and national measures, as found elsewhere.[15] This suggests quarantine was effectively achieved in a timely manner, even before the state of emergency was decreed, which has not been reported previously, as most studies consider all interventions together, without comparing the differential effects of quarantine alone or in combination with lockdown measures.[20]

Our findings suggest that cases in the intervention group had more household members than cases in the control cohort before the state of emergency declaration. It is important to notice that the number of household members is relevant only if those members are susceptible to being infected, that is, if they are not COVID-19 cases. To account for that, we also measured and compared the number of household members not infected at the time of the notification. As no difference was found, one may assume that populations across groups were similar.

To the best of our knowledge, this is one of the first observational studies addressing the empirical effectiveness of contact tracing and quarantine to control COVID-19 in the community. Published studies on this topic usually rely on mathematical models that predict, rather than demonstrate, the effectiveness of those measures.[20] This study, on the contrary, has comprehensive data on the actual evolution of COVID-19 outbreak in a community with more than 100 000 people. Because data were collected for epidemiological surveillance purposes, allowing for timely public health action, we firmly believe that information bias was reduced.

The study has some limitations that should be considered. Contact identification is highly dependent on the information provided by COVID-19 cases or their caregivers. We cannot exclude the possibility that some contacts may not have been identified, with all downstream implications. In aadition, asymptomatic close contacts were tested without formal indication during the quarantine period, which may have affected the primary outcome measures in both groups. Travelers from affected countries were often unknown to local authorities before their diagnosis, thus limiting the ability to block the transmission chain in this population. Some cases may have been under surveillance by another local public health authority without our knowledge, meaning they were misclassified as control, which may have also contributed to the underestimation of the true effects between groups regarding our primary outcome measures. Finally, it is possible other national measures with a lesser impact may have contributed to some residual confounding.

Conclusion

Local public health measures are effective at reducing both the time between symptom onset and laboratory diagnosis and the median number of close contacts per case. No effect was apparent on secondary cases figures, suggesting that further measures may be required to break the transmission chain of COVID-19. Nevertheless, national restriction measures appear to have an impact on reducing transmission of SARS-CoV-2.

Author statements

Ethical approval

The study was authorized by local *Conselho Clínico e de Saúde*, a structure that promotes clinical and health governance in Eastern Porto. All collected data are part of the continuing public health investigation of an emerging outbreak, for which no ethical approval is required. Thus, individual informed consent was waived. Any personal data were treated with respect to the general data protection regulations implemented both nationally and internationally.

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Competing interests

None declared.

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